BINGHAM CANYON MINE
The World's Largest Open-Pit Mine

By

JOHN S. RAPP, Geologist
Division of Mines and Geology
and
HOLLAND SHEPHERD, Reclamation Specialist
Utah Division of Oil, Gas and Mining

Photo 1. Oblique aerial view of Bingham Canyon copper mine, often called "The Richest Hole on Earth." A mountain once stood where this huge bowl is now. At the top, the rim is nearly 2.5 miles from one side to the other. Underground mining operations that followed silver and lead veins first began here in the late 1800s. Later it was discovered that fine-grained, copper-bearing minerals were disseminated throughout this area. Although the percentage of copper in the rock was small, the total volume of copper was recognized as huge. Since open-pit mining operations began in 1906, five billion tons of material have been removed yielding more than 12

Although air and water are recognizable resources, the role and importance of minerals is much less appreciated because their identity is commonly hidden in finished products. Mineral resources are an integral part of our society and are essential to our quality of life. Protecting and enhancing the environment, as well as proceeding with the development of mineral resources in an environmentally sound manner, are not mutually exclusive. The mammoth open-pit Bingham Canyon copper mine in Utah is an interesting case study. At this mine, industrial technological innovation is striving to meet rigorous environmental goals as well as mineral production.

Mined land reclamation legislation in Utah is, in many ways, comparable with similar legislation in California. Both the Utah Mined Land Reclamation Act of 1975, and the California Surface and Mining Reclamation Act of 1975 address environmental impacts of mining operations. This article explains how current mining practices at the Bingham pit are meeting environmental challenges posed by past and current mining operations. Examining the mining and reclamation practices of other states may lead to more efficient and environmentally sensitive operations in California....*editor.*

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million tons of copper. Impressive amounts of gold, silver, and molybdenum (a metal used to strengthen steel) have also been recovered. In October 1977, the Bingham pit was placed on the National Historic Register. *Photos courtesy of Kennecott Utah Copper Corporation.*

INTRODUCTION

The largest open-pit mine in the world is located 26 miles southwest of Salt Lake City, Utah. A steel tower, if erected in the bottom of the pit, would have to be five times higher than the Eiffel Tower to reach the rim of the pit. Five billion tons of rock have been removed from this mine and, within the next 25 years, an additional three billion tons will be taken out. The Bingham Canyon mine, commonly called the "Bingham pit," was important in the economic development of Utah as a state, and was equally important in the advancement of mining technology (Figure 1, Photos 1 and 2).

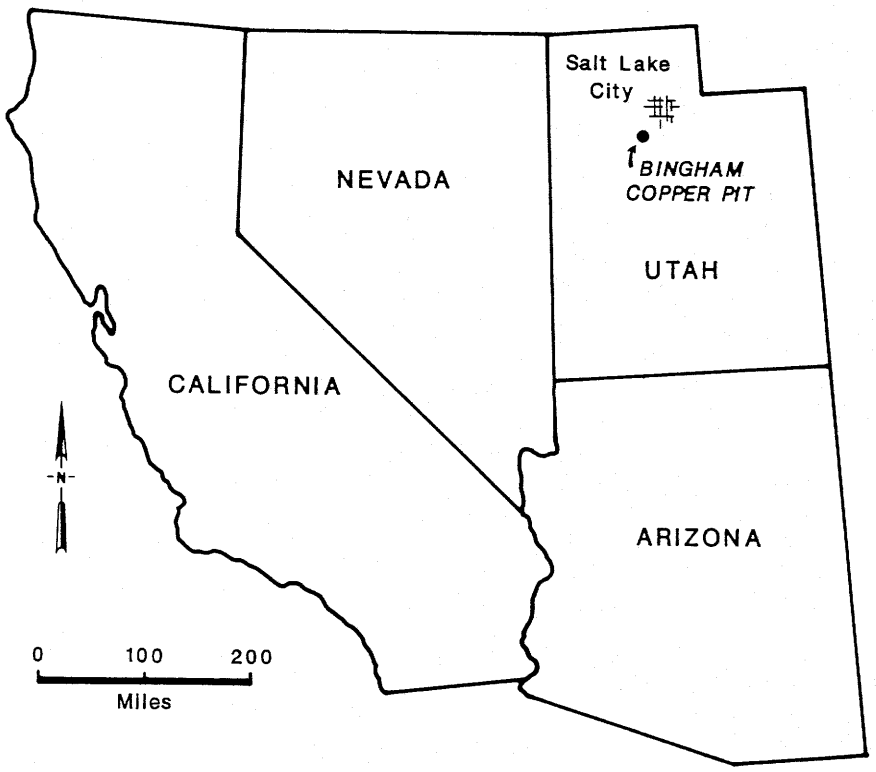

Figure 1. Location map (1:20,000,000 scale).

CALIFORNIA COMPARISONS

Large-scale open-pit metal mining operations today employ state-of-the-art equipment and methods. Precious metal deposits that were of little economic significance prior to World War II are being mined throughout California by methods originally developed at the Bingham Canyon mine. Large active open-pit gold mining operations in the California desert region include the Mesquite, Madre-Padre, and American Girl mines of Imperial County; the Colosseum and Morning Star mines of San Bernardino County; and the Standard Hill and Cactus mines of Kern County. The Sonora gold mine is located in Tuolumne County, and Homestake's McLaughlin mine is located in the Coast Ranges about 80 miles northwest of San Francisco.

Open-pit metal mines in California provide hundreds of well-paid mining jobs, and thousands of peripheral service and technical support jobs. Gold, silver, and base metals—such as copper, lead, and zinc—are recovered from these California mines and are used throughout the United States. None of these low-grade California mineral deposits would have been developed had it not been for technological advances that began at the Bingham pit.

HISTORY AND DEVELOPMENT OF THE BINGHAM CANYON MINE

In 1906 the Bingham pit became the first successful low-grade, open-pit copper mine in the world. Most mining "authorities" of the day proclaimed that low-grade (two percent) copper ore could not be mined profitably. However, by applying a new mining strategy that involved efficient large-volume mining methods, Daniel C. Jackling and a select group of American entrepreneurs proved them wrong.

The history of the Bingham Canyon mine is similar to other turn-of-the-century world-class mineral developments. A host of colorful and motivated mining engineers, geologists, metallurgists, and investors struggled and succeeded in opening mines and establishing mining companies that were truly remarkable for their day. At the height of the industrial revolution most Americans believed that wealth and individual accomplishment were essentially unlimited. In accordance with this conviction, a few notable pioneers of American mining created the Bingham Canyon mine.

The following historical section of this article was adapted from several anonymous articles, pamphlets, and brochures that chronicle the development of Bingham Canyon. These documents were prepared and distributed by Kennecott Utah Copper and regional historical groups.

Bingham Canyon

Bingham Canyon was named after a Mormon pioneer family that established grazing rights in the Oquirrh Mountains in 1848. Shortly after arriving, Erastus Bingham and his sons discovered mineralized rock in the Canyon, but were persuaded by the Mormon leader Brigham Young to terminate their prospecting activities and return to ranching. Because food was more important to the early settlers than copper and precious metals, the Bingham family moved to Ogden in 1850 and never returned.

In 1863, during the Civil War, a group of loggers working in the Oquirrh Mountains near Bingham Canyon

Photo 2. After-effect of blasting in the Bingham pit. A series of holes are first drilled into the pit "benches" then filled with liquid explosives. After the ore is blasted loose, it is picked up by huge electric shovels and loaded onto trucks. The electric shovel in the photo has a 30-cubic yard bucket with a 55-ton capacity. About 200,000 tons of material are removed daily.

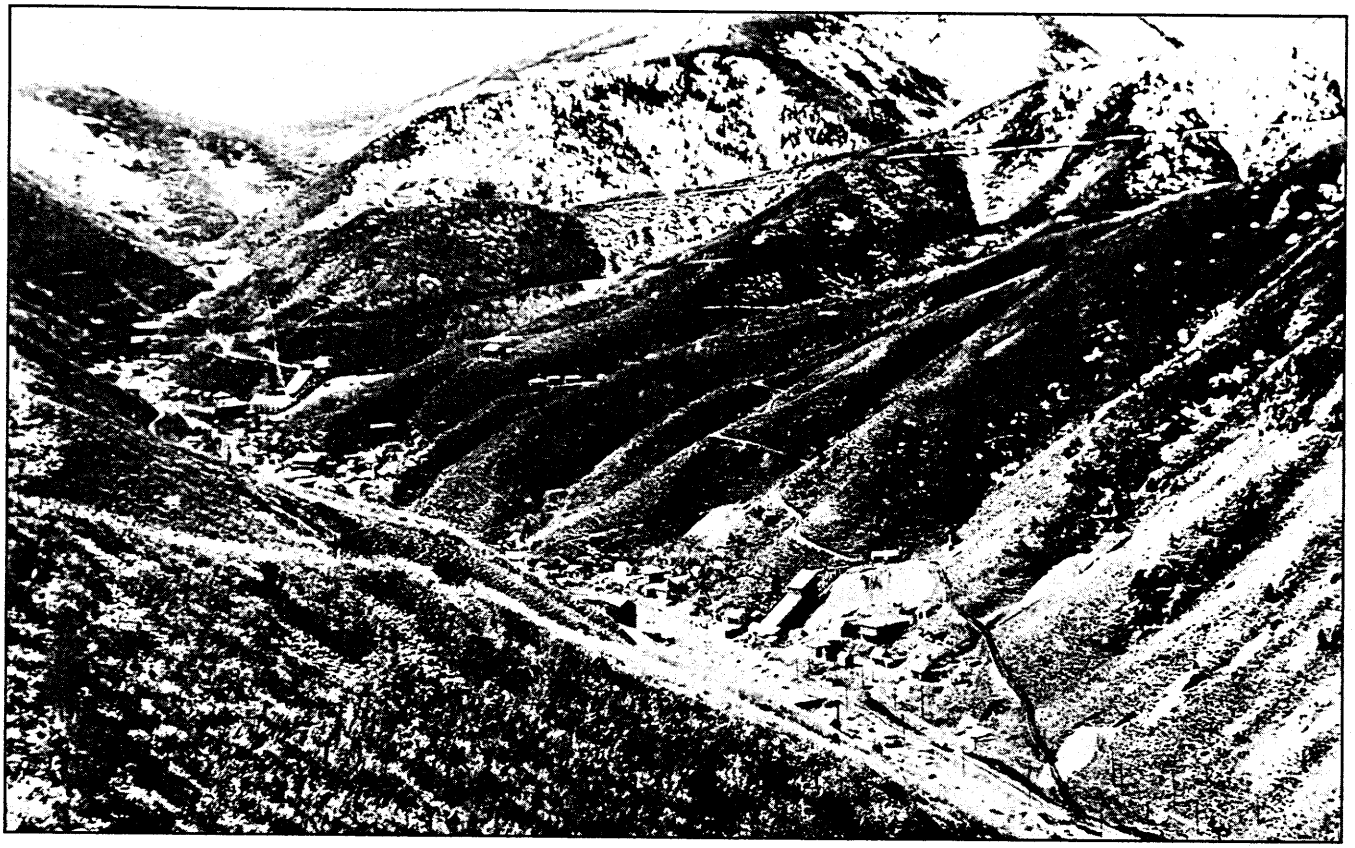

Photo 3. Bingham Canyon, Utah, 1904. Two years before open-pit mining operations began.

rediscovered the mineralized rock. They brought a hand specimen of silver and lead ore (argentiferous galena) to Colonel Patrick E. Connor, commander of the Third California Infantry at Fort Douglas, Utah. Some of Connor's men had prospected and mined in the Sierra Nevada gold fields of California before volunteering to serve in the Union Army, and may have recognized the potential value of the ore.

Impressed by the mineralized specimen from Bingham Canyon, Connor directed some of his men to prospect and develop mines there for the Union cause. Conner's orders were probably viewed as good duty because the first Bingham Canyon mineral locations were filed by his troops on September 17, 1863: just two days before the Battle of Chickamauga Creek, Georgia where 28,000 soldiers died.

Gold was discovered in 1864, but development was hampered by the isolation of the site. A railroad was constructed in 1873 and precious metal mining in the district flourished shortly thereafter. Copper was not the dominant metal mined in the Bingham District until the turn of the century.

In 1887 Colonel Enos A. Wall, recognizing the potential value of copper deposits in the Bingham Canyon area, began acquiring mining claims (Kennecott Utah Copper Corporation, 1987). Various investors and mine promoters also acquired and sold copper properties in the Bingham Canyon area. However, major development in the area began shortly after two engineers, Daniel J. Jackling and Robert C. Gemmell, were employed by Captain Joseph R. DeLamar to evaluate the Bingham Canyon deposit in 1899. DeLamar purchased a 25 percent interest in Wall's copper property for $50,000, and later sold that interest to Jackling and a group of investors for $125,000.

Jackling immediately enlisted the support of three prominent mining men; (1) Charles M. MacNeill, owner of United States Reduction and Refining, (2) R.A.F. Penrose, a renowned professor of economic geology at Chicago University, and (3) Richard Penrose. They arrived at Bingham Canyon in 1903 and formed the Utah Copper Company with $500,000 in assets derived from "penny stock" shares. Jackling continued to purchase properties and consolidate ownership, and by 1910, he had gained control of the Bingham Canyon deposit.

The Guggenheim Exploration Company of New York also bought into Bingham Canyon in 1905. The company had acquired American Smelting and Refining Company (ASARCO) earlier in 1901. ASARCO was awarded a long-term contract to smelt Bingham Canyon ore. Utah Copper Company commenced operations in 1906 (Photo 3).

Kennecott Copper Corporation purchased a 25 percent interest in the Utah Copper Company in 1915, a controlling interest in 1923, and sole ownership in 1936. Daniel J. Jackling continued to

manage the Utah Copper Company until 1942. In 1947 the Bingham Canyon operation formally became a division of Kennecott Utah Copper Corporation.

Kennecott Utah Copper Corporation merged with Sohio (Standard Oil Company of Ohio) in 1981. The Bingham Canyon operation continued to lose money in the early 1980s, and the mine eventually closed in 1985. Cost-cutting arrangements between labor and management, and $400,000,000 in modernization and capital improvements, allowed the operation to successfully reopen in 1987. That same year, British Petroleum Company took over Sohio and merged the assets of Kennecott Utah Copper Corporation with another acquired company, Amselco Minerals, Incorporated.

The British merger of these old mining companies resulted in the creation of British Petroleum (BP) Minerals America. In 1989 RTZ (Rio Tinto Zinc) Corporation, the world's largest mining company, purchased BP Minerals America and the Bingham Canyon mine. RTZ Corporation also owns U.S. Borax which operates California's largest mine; the Kramer borate pit in Kern County. Bingham Canyon mine is operated by Kennecott Utah Copper (KUC) Corporation, a division of RTZ Corporation.

GEOLOGY OF THE BINGHAM CANYON AREA

Bingham Canyon is a classic "porphyry copper deposit," the first of many to be developed in the southwestern United States. A porphyry copper deposit is a large disseminated metallic ore accumulation that forms from the intrusion of granite porphyry, and associated mineralized fluids. The ore mineralization collects into a receptive and permeable "host rock." "Porphyry" is an igneous texture term that refers to a rock containing conspicuous crystals within a fine-grained matrix.

At Bingham Canyon, Pennsylvanian and Permian age quartzite, siltstone, and fossiliferous limestone beds are folded and faulted. These Paleozoic rock units are intruded by sills and dikes of Tertiary granite and similar igneous rocks (Figure 2). Sills are "concordant" intrusions that parallel strata. Dikes are "discordant" intrusions that cut across strata. The most important igneous intrusive body—or pluton—in the area is the Bingham stock, a complex unit composed of biotite-granite, granite, and other similar rock types.

A series of Tertiary extrusive andesite and dacite tuff beds, flows, breccia units, and volcanic mudflows (lahars) are exposed at Bingham Canyon. The presence of volcanic dikes and other near-vent features suggests that Bingham Canyon was a center of Tertiary volcanism, and that volcanic vents may underlay massive lahars in the mine area.

Copper (bornite and chalcopyrite) and associated molybdenum (molybdenite) mineralization at Bingham Canyon is zoned within, and around, the Bingham stock like a halo. A disseminated zone of lead (galena) and zinc (sphalerite) mineralization envelopes the copper and molybdenum zone. This pattern also occurs within smaller mineralized fractures. The distribution of lead and zinc mineralization suggests that it may be largely controlled by the presence of carbonate host rocks.

Disseminated gold, silver (argentite), and several minor metals are present in significant amounts throughout the ore body. Silver values are higher at the periphery of the porphyry deposit. Metal values are highest in mineralized quartz veins and fracture fillings. Manganese and barium minerals are present in the outer-most mineralized halo. Host rock alteration is pervasive throughout the ore body and occurs in a zoned pattern much like the array of metal sulfide minerals (Rubright and Hart, 1968).

CURRENT OPERATIONS

The Bingham Canyon mine is the world's largest man-made excavation. It covers three square miles and is approximately two and one-half miles wide at the rim of the pit and about 3,000 feet deep. Approximately two-thirds of Utah's annual mineral production comes from this one mine. Although California has a somewhat larger non-fuel mineral production than Utah, its production is derived from more than 1,100 producing and intermittent mines. The Bingham Canyon mine has yielded more than 12 million tons of copper metal, the value of which exceeds the combined value of production from the California Mother Lode, the Nevada Comstock, and the Alaska Klondike gold rushes by a factor of eight (Kennecott Utah Copper Corporation, 1986; 1987).

In January 1990 Kennecott Utah Copper Corporation announced plans to spend an additional $227,000,000 to expand the ore processing capacity at Bingham Canyon from 77,000 to 112,000 tons per day. When all the improvements are completed, KUC production will be approximately 270,000 tons of copper metal per year.

The entire mining operation encompasses approximately 23,000 acres of disturbance and includes the Bingham pit, waste rock dumps, leach dumps, mine water ponds, tailings ponds, offices, shops, and ore processing facilities (Kennecott Utah Copper Corporation, 1976). An additional 605 acres of disturbance have recently been added onto the existing acreage to accommodate Kennecott Utah Copper Corporation's Modernization Project that was initiated in 1987.

More than 2,000 full-time employees work at the Bingham Canyon mine and mill. An additional 600 are employed during periods of peak production. The operation has also created and maintained several thousand peripheral and support jobs throughout the Salt Lake area. The Bingham Canyon mine has generated most of Utah's mineral production over the past 80 years. The socio-economic impact of this mine has been notable and positive. However, because of its size and long-term history, Bingham Canyon has significantly impacted the surrounding environment.

ENVIRONMENTAL CONCERNS

Like all mining operations in the early 1900s, the Bingham pit was unregulated during its long development and throughout most of its productive history. Since the commencement of

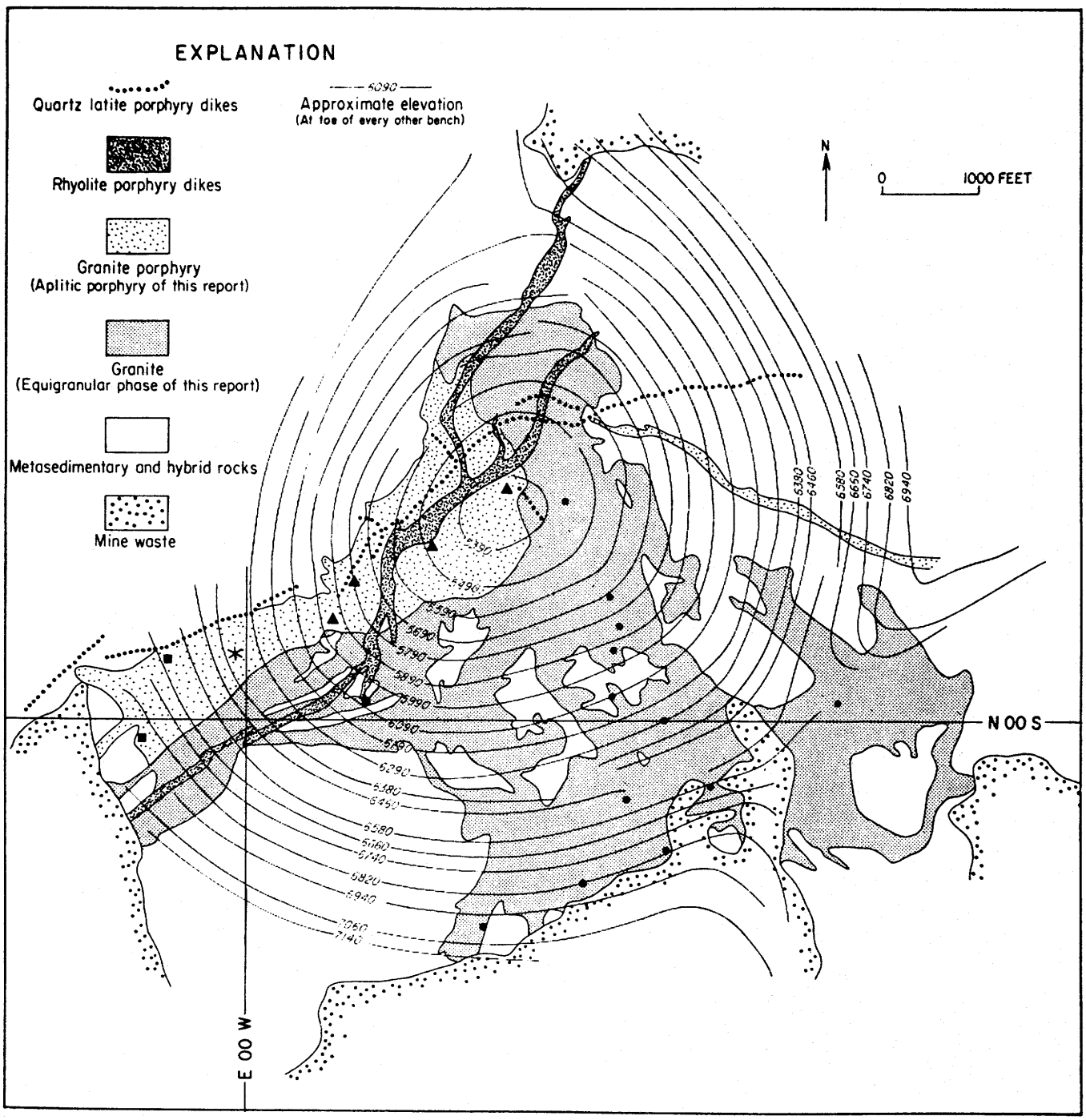

Figure 2. Geologic cross-section of the Bingham pit *(from Jensen and Bateman, 1981).*

operations in the early 1900s, much of the Bingham pit development occurred prior to the present-day appreciation of environmental impacts from mining or the passage of environmental legislation. Mining practices endorsed as state-of-the-art at that time are today viewed as environmentally unacceptable. In 1989 when RTZ Corporation (the parent company of Kennecott Utah Copper Corporation) purchased the Bingham pit, Kennecott's environmental programs were already underway. The company began operations under the requirements of the existing environmental legislation and addressed such issues as air and water quality, solid and hazardous waste disposal, and toxic materials control and reclamation. These programs are continuing and recent increases in environmental staffing allow Kennecott to not only emphasize existing and future operations, but also to actively mitigate earlier, pre-law effects of mining in the Bingham pit. Addressing the past, present, and future environmental issues will be an ongoing process.

Utah Mined Land Reclamation Act

The Utah Mined Land Reclamation Act (UMLRA), the first specific law addressing environmental impacts of mining in Utah, was enacted in 1975. UMLRA is administered by the Utah Division of Oil, Gas, and Mining. Briefly, the law requires that mine operators address environmental impacts made during the operational phase of mining and requires the operator to reclaim impacted areas at the completion of mining. For existing operations, such as the mammoth Bingham Canyon mine, this Act posed a monumental compliance problem.

Regulatory requirements of the Act do not extend to mining disturbances made prior to 1975 unless those areas are undergoing active operations. However, because much of the original Bingham pit was still in operation after 1975, the mining site had to comply with UMLRA legislation.

The State of Utah recognized the problem of bringing such a massive operation into compliance with UMLRA. Permitting regulations involved the approval of ongoing mining with contemporaneous reclamation operations. The reclamation plan was designed to evolve and incorporate new reclamation technology devised by KUC's own research. The biggest challenge of this plan is to develop reclamation techniques for areas previously impacted by mining. This research effort is currently being undertaken.

In addition to addressing reclamation standards required by the UMLRA, KUC must also address the requirements of the Federal Clean Water Act, Clean Air Act, and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), administered by the Utah Division of Environmental Health. Such requirements deal with groundwater and surface water quality, waste disposal, and air quality. Considerations of how the mining operations at the Bingham pit impact air and water quality, and how to mitigate such impacts have been the most problematic for KUC in recent years. In particular, smelter effluent, tailings dust, and groundwater impacts have been, and continue to be, difficult issues to resolve.

Kennecott Utah Copper Environmental Affairs Program

Kennecott Utah Copper Corporation recently increased its team of environmental specialists and engineers who work within the KUC Environmental Affairs Program. This program has done well in initiating an aggressive new program of stabilizing and vegetating some of the oldest and most problematic areas in the Bingham pit operation. The Environmental Affairs Program is also making significant headway in alleviating mining operation impacts on groundwater.

Groundwater

Hundreds of acres of waste rock dumps, leach dumps, evaporation ponds, and the pit itself have created groundwater problems in the Jordan River Valley east of the mine. Leachates originating from these facilities have caused the degradation of local aquifers. The degradation originates from the oxidation of sulfide minerals found in ore bodies associated with the mine (Dames and Moore, 1984). Key indicators of groundwater degradation include Total Dissolved Solids (TDS), sulfates, and acidity or low pH levels. Low pH is associated with elevated levels of heavy metals such as iron, copper, arsenic, selenium, cadmium, cobalt, chromium, nickel, and zinc (Utah Groundwater Technical and Advisory Group, 1988).

To counter this groundwater problem, KUC and the Utah Division of Environmental Health agreed on a comprehensive three phase plan to prevent further degradation of local aquifers. Currently, the plan has been implemented through the second phase. In addition to this three phase plan, a five year hydrogeologic study describing the mining impact on aquifers adjacent to the Bingham pit has been completed by the Joint Kennecott Utah Copper Mine Hydrogeologic Study (Utah Groundwater Technical and Advisory Group, 1988). Information from this study will be used to determine what clean-up measures may be appropriate and feasible. Discussions have not yet been finalized regarding the extent of these measures (personal communication with the Utah Division of Environmental Health, Bureau of Water Pollution Control, July 1990).

Dust

As a result of an economic downturn that occurred in the early 1980s, the Bingham pit mining operation was shut down. This action inactivated the 5,000-acre tailings pond, and caused a dust problem from blowing tailings. As a means of addressing airborne dust concerns, Kennecott Corporation began a comprehensive dust suppression program. The program consists of vegetating portions of the inactive exterior slopes of the tailings pond, an improved peripheral discharge spreading system on the active tailings sites, and chemical treatment of roads (Kennecott Utah Copper Corporation, 1988). This new approach has proven very successful in reducing dust levels (personal communication with the Utah Division of Environmental Health, Bureau of Air Quality Control, August 1990). Since the start-up of the facilities in 1988, there have not been any violations of the National Ambient Air Quality Standards in the adjacent community. Extensive inactive tailings areas, although considered pre-law disturbances under UMLRA, have also been revegetated by the KUC Environmental Program.

Waste Rock

One major hurdle that KUC has not yet tackled is the 8,000 acres of unreclaimed waste rock dumps. These dumps pose problems of erosion, surface and groundwater quality degradation, and the exclusion of productive land uses. They range in height from 1,000 to 1,200 feet and are at the angle of repose—the angle at which loose material comes to rest. Some dumps contain pyritic minerals and produce acid effluent; they present a major challenge for revegetation efforts. Plans and research to establish a vegetative cover on these dumps are being developed.

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Lucy Birdsall Memorial

Lucy Birdsall, U.S. Geological Survey Public Inquiries Officer in Los Angeles since 1953, died October 21, 1990. Lucy enlisted in the U.S. Women's Army Corps in 1943 and served in the Philippines and New Guinea during World War II. After being honorably discharged as a sergeant, Lucy used the G.I. Bill to complete her bachelor of science degree in geology at the University of Connecticut. In 1953, after having worked in the U.S. Geological Survey (USGS) Geophysical Branch in Washington, D.C., she transferred to the USGS office in Los Angeles. At the Los Angeles office Lucy was instrumental in opening the USGS Public Inquiries Office where she served for 34 years. She retired from the USGS in 1987.

Lucy was outgoing and had a characteristic New England accent. Her enthusiasm and dedication notably increased public awareness of geology. She was a primary earth science information source in the Los Angeles region. Many thousands of people, including geologists, geology students, city officials, media people, school children and the public, benefitted from her expertise and competence.

Lucy E. Birdsall, 1914-1990. *Photo courtesy of the U.S. Geological Survey.*

She was a female geologist at a time when there were very few and was active in earth science programs throughout her distinguished career. Her alma mater, the University of Connecticut, honored her as a Distinguished Alumna. She was president of the Branner Club (a geological organization in the Los Angeles region), president of the Los Angeles Basin Society, president of the American Association of Petroleum Geologists—Pacific Section, honorary member of the South Coast Geological Society, a director of the Thomas W. Dibblee, Jr. Geological Foundation, member of the Geological Society of America, member of the Los Angeles Mineralogical Society, and regularly attended the Southern California Section of the Association of Engineering Geologists.

In recognition for her work at the USGS, Lucy received the Department of the Interior Distinguished Service Award for Meritorious Service. The Dibblee Foundation is honoring her by naming its next map in the Santa Monica Mountains the Lucy Birdsall map. Donations may be sent to: Dibblee Geological Foundation, P.O. Box 60560, Santa Barbara, CA 93160. In tribute, the South Coast Geological Society established the Lucy Birdsall $500 annual scholarship to be awarded to a geology student. Donations may be sent to: Lucy Birdsall Annual Scholarship Fund, South Coast Geological Society, P.O. 10244, Santa Ana, CA 92711-0244. *By Dorothy L. Stout.*